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THE SMUTS OF WHEAT, OATS, BARLEY, AND CORN.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., May 25, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication as a Farmers' Bulletin the accompanying manuscript, entitled "The Smuts of Wheat, Oats, Barley, and Corn," prepared by Edward C. Johnson, Pathologist in Charge of Cereal-Disease Work, Office of Grain Investigations.

This paper shows that the smuts continue to be of great economic importance, gives popular descriptions of them and their life habits, and points out the best methods for their prevention. The publications of the State agricultural experiment stations and of this Bureau have been freely used in its preparation, but many observations and deductions based on original investigations are also included.

The author acknowledges his indebtedness to the State grain inspectors and representative millers who courteously furnished information concerning the market receipts and the grading of smutted wheat.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE SMUTS OF WHEAT, OATS, BARLEY, AND CORN.

INTRODUCTION.

Methods for preventing the more important grain smuts have been known and used more or less extensively in this country since about 1890. The losses from smuts, however, are still surprisingly large. They are of two kinds: (1) Those in the field where smutted plants take the place of sound plants and (2) those in marketing when noticeably smutted wheat receives a lower grade than smut-free wheat and is often rejected. The field losses in the United States in 1911, as estimated by the Office of Grain Investigations, were as follows: From stinking smut of wheat, 1.7 per cent of the total wheat crop, or 10,562,746 bushels, valued at \$9,232,071; from smut of oats, 4 per cent, or 36,891,920 bushels, \$16,586,520; from covered smut of barley, 1 per cent, or 1,602,400 bushels, \$1,391,820; from loose smut of wheat, 0.85 per cent, or 5,281,373 bushels, \$4,616,035; from loose smut of barley, 1.2 per cent, or 1,922,880 bushels, \$1,670,184; a total field loss of \$33,496,630. The loss to the individual producer who grows smutted crops is, of course, much greater than the average percentage for the United States. In fact, in many of the fields in Pennsylvania, New Jersey, Wisconsin, Minnesota, and other States visited in 1911 more than 10 per cent of the grain was smutted, and in one field on land valued at \$100 an acre more than 40 per cent of the crop consisted of smutted heads.

On the market, wheat affected with stinking smut to any considerable degree brings a lower price than smut-free wheat, because it can not be used for first-grade flour unless it is thoroughly washed and scoured. When the wheat is not too smutty, such cleaning can be done at nominal expense by mills which have the necessary cleaning machinery, but many mills in which such machinery is not installed reject all smutty wheat, and the producer gets a lower price for his product. This loss in 1911, as estimated from figures given in letters from State grain inspectors and representative millers, was equal to a reduction of one grade for at least 20 per cent of the total wheat crop of the United States, or one grade for 124,267,600 bushels. The price per bushel is reduced on an average at least 2 cents for each

reduction in grade. The loss from this source in 1911, therefore, would be \$2,485,352. With this added to the field loss, a total loss of \$35,981,982 was suffered by the producer because of smuts in small grains during this one year.¹ Losses from smut in corn were not estimated, but if included they undoubtedly would increase this amount by several million dollars. The year 1911 was not an unusual smut year but rather below the average, and losses in other years may be far greater.

With the exception of smut in corn, all the smuts discussed in this paper are preventable, and that they still continue to do so much damage is due to several causes. Many farmers do not know that smuts are present even if 2 to 10 per cent of the crop is affected; others recognize them but do not know that they can be prevented, or have neither time nor money to do work the value of which is not immediately evident or clearly understood; still others employ preventive methods but use them incorrectly and therefore without success, while no organized community effort to eradicate smuts has yet been tried. It is the aim of this paper to describe the smuts so that farmers may recognize them and know something of their life habits; also to describe the best preventive methods known to-day and to show how they may be applied correctly and successfully.

HOW TO KNOW THE DIFFERENT SMUTS.²

THE STINKING SMUT OF WHEAT.

The stinking smut of wheat, often called "bunt," is easily distinguished in the field when the grain is almost ripe. The smutted plants are usually slightly stunted and the heads stand more erect than the heavy sound heads. The chaff is spread apart more or less by the dark swollen kernels. When the tough membrane or skin of such a kernel is broken a dark, seneary, dustlike mass is disclosed, which has a peculiar fetid odor like that of decaying fish. This odor may often be noticed at a distance of several rods to leeward of a badly smutted field. The loss due to this smut results not only from the destruction of the kernels of diseased plants, but also from the dockage in marketing grain from smutted crops. There are two kinds of stinking smut, but they are so much alike in appearance and general character that for practical purposes they may

¹The total production and farm value of wheat, oats, and barley, as estimated for the United States for 1911 by the Crop Reporter, vol. 13, No. 12, Jan. 5, 1912, were used in computing the losses from smuts in bushels and dollars.

²The smuts discussed in this bulletin are the stinking smuts of wheat, *Tilletia foetens* (B. and C.) Trel. and *Tilletia tritici* (Bj.) Wint.; the loose smut of wheat, *Ustilago tritici* (Pers.) Jens.; the covered smut of barley, *Ustilago hordei* (P.) K. and S.; the loose smut of barley, *Ustilago nuda* (Jens.) K. and S.; the smuts of oats, *Ustilago laevis* (K. and S.) Magn., and *Ustilago avenae* (Pers.) Jens.; and the smut of corn, *Ustilago zeae* (Neckm.) Ung.

be regarded as the same. Figure 1 shows a smutted head of wheat and smutted kernels and for comparison a sound head and sound kernels.



FIG. 1.—Stinking smut of wheat, showing a smutted head and smutted kernels or smut balls and for comparison a sound wheat head and sound kernels.

THE LOOSE SMUT OF WHEAT.

The loose smut of wheat is most noticeable at the heading time of the grain. In the smutted heads the kernels and chaff are replaced by a dark, sooty mass which is soon blown away by the wind, leaving bare stems that are usually not noticed at harvest time. All such smutted plants are a dead loss in the crop and sound plants should have been in their place. Figure 2 illustrates the effect of this smut.

THE COVERED SMUT OF BARLEY.

The covered smut of barley is most noticeable several days after the barley is fully headed. The smutted heads are darker in color than sound heads and the kernels are composed of greenish black

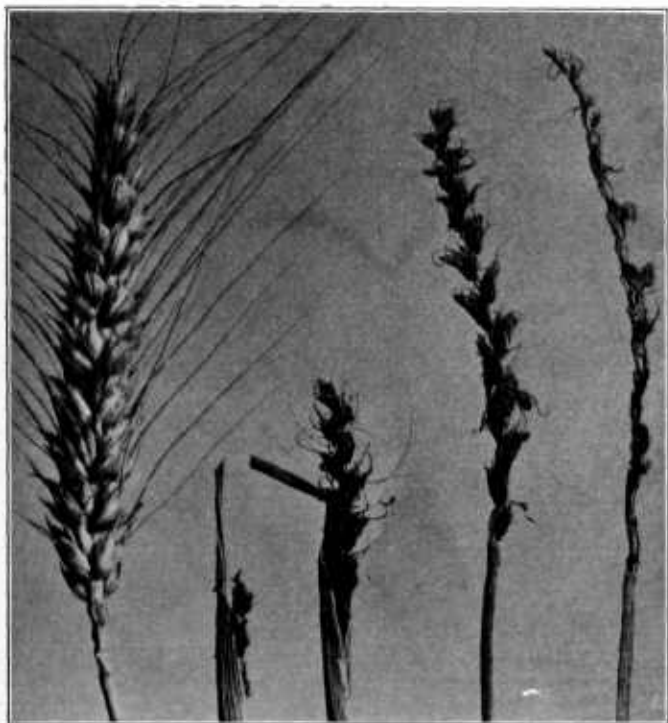


FIG. 2.—Loose smut of wheat, showing four smutted heads at various stages of development and for comparison a sound wheat head.

masses of smut. These are not blown away by the wind but remain until the grain is harvested and thrashed, when the smutted heads are broken. Many of the smut masses are not separated by the

thrashing machine but remain in the grain, smearing it with smut. Figure 3 shows two barley heads, one sound and one affected with this smut.

THE LOOSE SMUT OF BARLEY.

The loose smut of barley is most noticeable at heading time, the smutted heads being composed of dark, sooty masses which are blown away by the wind exactly as in the loose smut of wheat, leaving the erect stems without heads. All such smutted plants are a dead loss. A sound barley head and several smutted heads are shown in figure 4.

THE SMUT OF OATS.

The smut of oats is most easily noticed a little before the grain is ripe, when smutted plants are found to be shorter and to stand more erect than sound plants. In place of the kernels there are dark masses of smut dust, which sometimes are covered by the chaff and sometimes are left fully exposed. Like the stinking smut of wheat, this smut is of two kinds, which are so similar that for practical purposes they may be handled as one. A greater percentage of the crop is destroyed by this grain smut than by any other. Figure 5 shows a smutted and a sound head.

THE SMUT OF CORN.

Corn smut is unlike the smuts of the small grains in that it not only occurs on the head, or tassel, and on the ears, but also on the stalk. When present it is very noticeable as it forms dark smut boils or masses on various portions of the corn plant. As a rule, however, it is less destructive to the corn crop than the other cereal smuts are to the small grains. Figure 6 shows a young ear affected with smut.

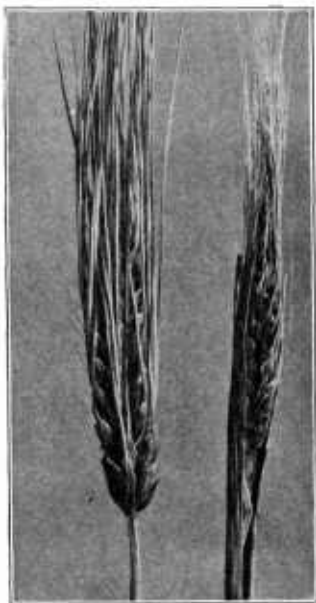


FIG. 3.—Covered smut of barley, showing a smutted head and for comparison a sound barley head.

SMUT CHARACTERISTICS AND LIFE HABITS.

GENERAL DESCRIPTION OF SMUTS.

The smuts are plants which live in the tissues of other plants, such as grains and grasses, and produce the dark, sooty masses from which they receive their names. They are composed of numerous fine, almost colorless threads, or runners, and steal their nourishment from the food prepared by the green plants for their own use. In



FIG. 4.—Loose smut of barley, showing five smutted heads at various stages of development and for comparison a sound barley head.

fact, a smut can not long grow outside a living plant. When the smut-infected plant is about to mature, seed formation is often prevented and the smut forms the smut masses, composed of large numbers of very small dark bodies called spores. These, like seeds, may germinate immediately or lie dormant from season to season and serve to propagate the smut from one crop to another.

There are many kinds of smuts. These resemble each other in many of their life habits, but in other respects they differ and are just as distinct as the various kinds of green plants. Thus, smut from barley can not live in wheat or oats, smut from wheat in oats or barley, smut from oats in barley or wheat, or smut from corn in any of the small grains.

Smuts are found and thrive under practically all conditions and in all climates where grain crops are grown. Thus, the loose smuts are abundant not only in the humid regions of the East but also in the semiarid regions of the West. The same is true of the other smuts of wheat, oats, and barley. Although some years seem to favor their growth more than others and extreme humidity or drought has considerable influence on the prevalence of all of them, they are rarely, if ever, entirely absent.

The life habits of the smuts are very similar. There are some differences, however, which will be brought out in the following paragraphs.

THE LIFE HABITS OF STINKING SMUT OF WHEAT.

The dark-colored kernels in heads affected with stinking smut of wheat contain a dustlike mass. This mass is composed of thousands of smut spores. When grain from a smutted crop is being thrashed and handled in sacks, bins, and machinery, the smutted kernels, or so-called smut balls, break and the smut spores are scattered over the sound seed. When such seed, covered with spores, is sown and ger-



FIG. 5.—Smut of oats, showing a smutted head and for comparison a sound oat head.

minates, the smut spores germinate also, forming a second kind of spores from which smut plants are developed. These can not manufacture their own food from the soil or live alone very long, but send forth little tubes or filaments which attack the sprouting wheat plants below the ground line, penetrate them, and finding satisfactory

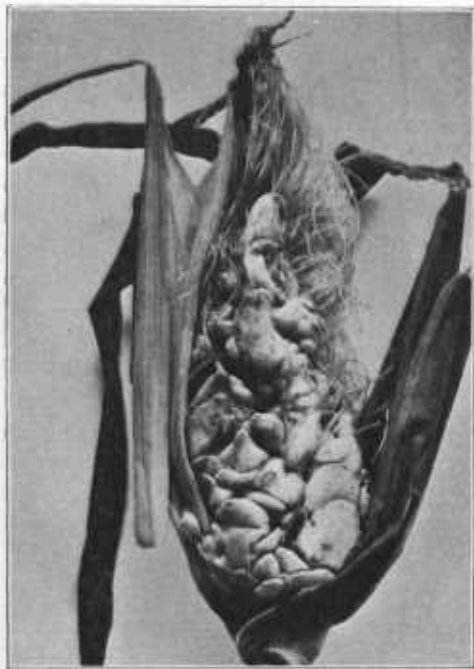


FIG. 6.—Smut of corn, showing a young smutted ear.

location and suitable food live and thrive inside until the grain is about to mature. They then take full possession, develop the smut masses, and do not permit the grain plants to form any seed. Such smut masses are mature when the grain is ripe and they break in thrashing and handling. The spores then fall among the seed and are ready to germinate the following season.

THE LIFE HABITS OF COVERED SMUT OF BARLEY AND SMUT OF OATS.

The life habits of the covered smut of barley and smut of oats are very similar to those of stinking

smut. The smutted kernels more often break in the field, however, than in wheat smut, and the smut spores are scattered by the wind. Some of them lodge under the chaff of the grain in sound plants and thus contaminate the seed, while other smut masses are broken up in harvesting and thrashing, and the spores get on the seed just as in the case of stinking smut. For practical purposes, however, the life

habits of these smuts may be considered the same as that of stinking smut.

THE LIFE HABITS OF THE LOOSE SMUTS OF WHEAT AND BARLEY

The loose smuts of wheat and barley are slightly different in their life habits from the smuts just described. These smuts mature and their spores are ripe when the grains are in bloom; consequently they are most noticeable at heading time. The spores are soon blown away by the wind, and some fall on the flowers of the wheat or barley. When the spores from the wheat smut fall on wheat flowers and those from the barley smut on barley flowers, they germinate and send a little filament or germination tube into the young kernel. As the kernel enlarges, a tiny smut plant is formed inside of it but remains hidden and allows the kernel to fill like any other seed. When such a kernel is planted the following season and starts to grow, the smut plant grows also and develops inside the grain plant much as the stinking smut of wheat. When the heading time is at hand the smut plant prevents the formation of a sound head, matures, and forms the smutted head, composed of a mass of spores, which are soon blown away by the wind to infect sound plants which are in bloom. Thus it provides for its continued life the next year.

THE LIFE HABITS OF THE SMUT OF CORN.

The life habits of corn smut differ considerably from those of the other smuts. The large smut masses, or smut boils, which occur on any part of the corn plant, contain hundreds of thousands of spores, which generally are mature before the corn is ripe. Many of these fall to the ground; others remain in the large masses of smut on cornstalks and refuse in the field or find their way into the barnyard, where they get into the manure. In the moist, warm days of spring these spores germinate and produce millions of another kind of spore. These are very tiny, colorless, and very light. The wind catches them up and distributes them over large areas. Some fall on the young growing tissue of the corn plant, such as tassels in flower, fresh silk, or young parts of the stalk. Here they start to grow, sending out tiny tubes, or filaments, which penetrate the corn plant, infect it, grow, and produce new smut masses.

THE THREE GROUPS OF GRAIN SMUTS.

From the foregoing description of their life habits it is seen that these grain smuts naturally fall into three groups. To the first belong the stinking smut of wheat, the covered smut of barley, and the smut of oats, whose spores are mature when the grains are ripe, are distributed in harvesting, thrashing, and handling in sacks and machinery, and lodge on the outside of the seed or under the hull. To the second

belong the loose smuts of wheat and barley, whose spores are mature when the grains are in bloom, are scattered by the wind at heading time, and lodge in the flowers of the grain, forming little smut plants within the kernels. To the third belongs the smut of corn, whose spores generally mature before the corn is ripe and live from one season to another on the ground, in smut masses on old cornstalks, and in manure.

On account of these differences it is not possible to prevent the three groups of smuts in the same way, special methods being necessary for each group. The more important of these are described in the following pages.

THE PREVENTION OF SMUTS.

IMPORTANCE OF CLEAN SEED.

Since the stinking smut of wheat, the covered smut of barley, and the smut of oats are propagated from year to year, principally by means of the spores clinging to the outside of the seed, clean seed is of prime importance in order to grow a crop free from these smuts. This may be obtained in two ways: (1) By using seed from a crop which had no smut in it and which has been kept clean or (2) by treating the seed by some method which will kill the smut and leave the seed uninjured. The former method seems easy at the first glance and should always be used where the seed is not treated for smut. It has some disadvantages, however. It is almost impossible to know whether or not a crop is absolutely free from smut unless it has been examined very carefully before it is cut. Even then, if there are only a few smutted heads they may not be noticed. Each one of these produces thousands of spores which may become distributed over the seed, so that a smutted plant of one year may give rise to hundreds the next. Again, if the crop is absolutely free from smut but is thrashed in a machine that has just been used with a smutted crop, innumerable spores found inside of the machine on the cylinder, in concave grooves, sieves, shaker, etc., will get on the seed and cause smut the following year. Sacks, bins, fanning mills, or other machinery which have been used for smutted grain, unless disinfected, will spread the smut more or less in a similar manner. In a community where smut is present, therefore, one can not always be sure that a crop will be free from the smut because the seed came from a crop that was clean the preceding year. In such communities the second method, namely, to subject the seed every year to some treatment which will kill the smut spores but leave the seed uninjured is the most effective way to prevent these smuts until the community as a whole is smut free. Several treatments are known which are very satisfactory. These are described on pages 15 to 23.

For the loose smuts of wheat and barley clean seed from a clean crop is a good remedy. These smuts can not be distributed in thrashing or by smutty machines of any kind, as they must infect the seed at the flowering time if they are to produce smutted plants the next year. These are very easily seen in a field if it is examined when the grain is heading. Seed from a crop apparently clean, therefore, is likely to produce a clean crop the following year. There is, however, some uncertainty even here. If a clean crop has been grown in a neighborhood where loose smuts are prevalent, the spores from smutted fields may have been blown by the wind into the clean field. The flowering grain may thus have been infected and seed from this field would very probably produce some smut the following year. The best way to produce crops free from the fungus is to use seed from neighboring localities where smuts are absent, if such can be found, or from an isolated plat set aside for seed purposes, seed for this plat having been treated by the so-called modified hot-water treatment. This is described on pages 26 and 27.

The smut of corn, as already described, does not live from one year to another on the seed, and seed treatments are therefore useless. In fact, there are no certain methods for preventing this smut, but some measures which may help to reduce its prevalence are known and are described on page 28.

TREATMENTS OF STINKING SMUT OF WHEAT, SMUT OF OATS, AND COVERED SMUT OF BARLEY.

A large number of treatments for the prevention of stinking smut of wheat, smut of oats, and covered smut of barley are known, and several of these have proved equally efficient for all of these smuts. They consist in soaking the seed in some solution which will kill the smut spores but will not harm the seed. Many such disinfecting solutions are known and all have been found more or less effective. Hot water, sar solution, copper sulphate or bluestone, and formalin are the most important of these treatments, and the two latter have been used extensively in this country.

THE HOT-WATER TREATMENT FOR STINKING SMUT OF WHEAT AND SMUT OF OATS.

The hot-water treatment for stinking smut of wheat and smut of oats consists in soaking the seed in hot water at a temperature of 132° to 133° F. for 10 to 15 minutes.¹

¹ The hot-water treatment devised by Jensen, Copenhagen, Denmark, in 1887 (see Journal of the Royal Agricultural Society of England, ser. 2, vol. 24, pt. 2, 1888.), was tested by Kellerman and Swingle, was improved and recommended by Swingle (see Farmers' Bulletins 75 and 250, U. S. Dept. of Agriculture) in the United States, and has been tested by many other investigators. Its effectiveness has been repeatedly demonstrated by Bolley, Freeman and Johnson, and others and their results have been further substantiated by a large number of experiments by the writer, the detailed results of which have not yet been published.

The seed is then dried and may be sown immediately. On small farms where 50 to 100 bushels are to be treated, the hot-water treatment may be used successfully with simple apparatus. This consists of some means of heating the water, such as a large kettle or boiler, three large barrels or vats, pails or baskets with perforated bottoms, sacks, and a good thermometer. A good thermometer is absolutely necessary for all hot-water treatments,¹ as the use of an instrument which is not accurate will result in injury to the germinating power of the grain on the one hand or in failure to prevent the smut on the other. The baskets can be made by perforating the bottoms of ordinary galvanized-iron or tin pails, or small tubs with numerous holes or special galvanized-iron baskets may be ordered from the tinsmith. These should hold from one-half to a bushel of grain, and the bottom should be made of strong, fine-wire screen or of closely perforated tin plate. The holes should not be so large that kernels of wheat will go through. Two such baskets are sufficient, but three or more often prove convenient.

The barrels are numbered 1, 2, and 3, respectively. Hot water from the kettle or boiler is poured into barrels Nos. 1 and 2 until they are a little more than half full, and cold water is put in No. 3. The temperature of the water in barrel No. 2 is then brought to 133° F. by pouring in cold or hot water as needed, while the water in No. 1 is kept at 115° to 120° F.

A basket is now filled two-thirds full with the grain to be treated. This is first dipped into barrel No. 1 so that its temperature will be raised to very nearly 120° F. After a few moments it is removed, drained, and dipped into barrel No. 2, where it is kept for 10 to 15 minutes at a temperature of 132° to 133° F., the basket being rotated and moved up and down so that all portions of the grain will be equally heated. The temperature, which must not rise over 135° F. or fall below 130° F., is kept even by pouring in hot or cold water as necessary and keeping the water constantly stirred. It is exceedingly important that the right temperature be always maintained, and usually it is well to have one person whose chief duty it is to attend to this. All smut balls should be skimmed off by means of a hand skimmer or other device as they rise to the surface. At the end of the

¹ Thermometers may be submitted to the Bureau of Standards, Washington, D. C., for test. A charge of about 50 cents will be made for testing at the two points necessary. They should be graduated in single degrees (Fahrenheit) directly upon the stem or upon a scale contained within the stem and should preferably read from 0° to 212°. The bulbs, at least, should be made of a suitable glass, such as Jena "normal" thermometer glass or Corning "medium" thermometer glass, in order that the readings may not change with time, and the general construction of the thermometer should be good. However, thermometers with the Bureau of Standards' certificates can be purchased directly from manufacturers or large dealers, and this is generally a much more convenient way to secure them, because it avoids the risk and expense of shipping them to and from Washington.

time stated the grain is removed and immediately spread out to dry. If it can not be spread immediately it must be dipped into cold water to cool it off, and spread soon thereafter; otherwise the power of germination will be injured. The process is then continued until all the seed is treated.

On farms where live steam is available from traction or stationary engine boilers the hot-water treatment is easily performed. In place of three barrels only one large vat or tank need be used. The boiler is connected with the tank by means of steam pipes entering near the bottom, so that the steam can be admitted and diffused without coming in direct contact with the grain which is being dipped. Water is poured into the vat, heated to 132° or 133° F., and kept at this temperature by admitting and cutting off the steam as required, while the grain is dipped in the usual manner.

The seed is best dried by spreading it in a layer not more than 3 inches deep on a floor or canvas which is free from smut spores or which has been cleaned with boiling water. Here it is shoveled over from time to time to facilitate drying.¹ As soon as it is sufficiently dry to run freely through the drills it may be sown. Allowance must then be made for the swollen seed. The increase due to swelling is usually 10 to 20 per cent by volume and can be estimated by measuring the seed before and after treatment. The seed may be treated several months before seeding time and then dried quickly and carefully. The grain germinates as well or better when rested after treatment than if sown immediately. It must not be allowed to sprout. Care must be taken to prevent its freezing when moist, as this will impair germination.

Before sowing, the seed should always be tested for germination. This can be done by placing several lots of 100 seeds each between damp blotters or pieces of cloth and keeping them at a living-room temperature for several days. The percentage of sprouted kernels will show the power of germination. If this is low, a corresponding increase in the rate of seeding is necessary.

The hot-water treatment is very effective and could be used to great advantage on large farms or at central plants where farmers could go to have their seed treated. Undoubtedly machines can be devised for this treatment which will provide for the automatic regu-

¹A good drying apparatus is described by Swingle in *Farmers' Bulletin* 250, U. S. Dept. of Agriculture, 1900, as follows:

"One of the best drying outfits consists of a framework about 12 feet square made of 2 by 4 inch rafters set 3 feet apart and then lathed over, leaving about 1½ inches between the laths. This platform should be supported 1 or 2 feet above the ground, so the air can circulate freely underneath. Then the grain can be spread out on canvas over this platform and will then dry very rapidly. In all cases the drying floor or canvas should be disinfected with boiling water before the grain is spread out, and when the grain is put in sacks for drying the sacks must also be disinfected by dipping in boiling water."

lation of the temperature in the treating tank and for the immersion of the grain in it. Such machines would be very useful at the larger treating plants.

THE HOT-WATER TREATMENT FOR COVERED SMUT OF BARLEY.

The hot-water treatment for covered smut of barley is performed like that for the stinking smut of wheat and the smut of oats, but at a lower temperature. Barley seed is injured by temperatures over 130° F. and should be treated at temperatures between 126° and 129° F.

THE SAR TREATMENT.

Sar solution was devised by Mr. Walter T. Swingle, of the United States Department of Agriculture, in 1898. This solution consists of a mixture of sulphur, rosin, and caustic soda and is an effective preventive of stinking smut of wheat, smut of oats, and covered smut of barley. The treatment is given in detail in Farmers' Bulletin 250, United States Department of Agriculture. The following paragraph from this bulletin describes it briefly:

Sar solution is made by mixing 15 pounds of flowers of sulphur with one-half pound of powdered rosin, wetting with about 6½ quarts of water to a thick paste, then adding 10 pounds of dry powdered caustic soda (concentrated lye), stirring vigorously while the whole mass turns reddish brown and boils violently. Enough hot water is added to bring the solution up to 6 gallons. This stock solution is preserved in tightly corked jugs and must be shaken well before being used.

The seed wheat is treated with sar solution as follows: Either 1 quart of the solution is diluted with 50 gallons of water and the grain soaked therein for about 12 hours, or else a strong solution (1 gallon of the stock to 50 gallons of water) is used and the grain soaked only two hours. In either case the grain must be stirred several times during the treatment and spread out to dry afterwards. If the grain contains much smut it should first be washed with water in order to skim off the smut balls before it is put in the sar solution to soak.

The reluctance of farmers in general to use a treatment which seems at all difficult to prepare constitutes the chief objection to the sar solution.

THE COPPER-SULPHATE, OR BLUESTONE, TREATMENT.

The copper-sulphate, or bluestone, treatment¹ has been used very extensively in California, Washington, Idaho, and other States for preventing the stinking smut of wheat. It consists in treating the seed wheat with a solution of copper sulphate in water. In one method a solution composed of 1 pound of copper sulphate to 4 gallons of water is used. This is put into barrels or vats and the grain is immersed in it for a minute or so. As the smut balls rise to the

¹ An account of the successful use of copper-sulphate solution for the prevention of stinking smut was first published in France in 1807 by Prévost.

surface they should be skimmed off. When all kernels are thoroughly wet the grain is removed and dried, and it is then ready to be sown.

A second method is to use a solution composed of 1 pound of copper sulphate to 25 gallons of water and to soak the seed in this for about 12 hours. The seed is then removed and dipped for a few minutes in a lime solution composed of 1 pound of lime dissolved in 10 gallons of water, in order to stop any further action of the sulphate. This slow method of treatment, however, has gained very little favor because few farmers care to steep their seed for 12 hours and then to take it out and steep it in another solution before drying. They much prefer to do the work in one operation and be through with it. The seed may be sown as soon as it is sufficiently dry to run through the drills.

The main objection to the copper-sulphate treatment is that it will injure the seed to some extent. Even if the treatment is very carefully performed the solution will soak into and injure seed which has been scratched or slightly cracked in the thrashing machine. If not killed, such seed is weakened, so that the plants start in life severely handicapped. Oats and barley are more injured by this treatment than wheat and should never be treated in this way.

THE FORMALIN TREATMENT.

The possibilities of the formalin treatment for stinking smut of wheat were recognized in Germany in 1895.¹ In 1897 it was introduced into the United States by Prof. H. L. Bolley,² and since then has been tested by many investigators. Its effectiveness for stinking smut of wheat, smut of oats, and covered smut of barley when properly used has been repeatedly demonstrated in these tests, in practical results on farms throughout the country, and in numerous experiments by the writer. It is easily applied, inexpensive, and very effective and therefore is strongly recommended for the prevention of the three smuts here mentioned.

The formalin treatment consists of treating the seed with a solution of commercial formalin in water. Commercial formalin, which is a 40 per cent solution of formaldehyde gas in water, may be bought by the pint or in bulk from a druggist at a cost of 50 cents to \$1 per pound, and 1 pound (16 ounces avoirdupois) will treat 25 to 50 bushels of grain. The formalin solution should be guaranteed to contain 40 per cent of formaldehyde gas by volume. If there is any doubt as to its strength, a half-pint sample should be sent to the chemist at the State agricultural experiment station for analysis. If it is found to be considerably weaker than a 40 per cent solution it should not be used.

¹ See *Berichte der Deutschen Pharmaceutischen Gesellschaft*, vol. 5, 1895.

² See *Bulletin* 27, North Dakota Agricultural Experiment Station, 1897, pp. 109-162.

This formalin is mixed with water at the rate of 1 pound of formalin¹ to every 45 gallons of water. The grain is sprinkled or soaked in this solution until every kernel is thoroughly wet. After wetting, the seed is dried sufficiently to run through the drills, or if it is to be kept any length of time it is spread out on a clean floor or canvas and dried, so that it will not spoil when placed in sacks or bins. If the grain is sown immediately after treatment, considerably more than usual should be sown to the acre, as the water absorbed causes the grain to swell. The quantity which should be sown is determined by measuring a given bulk before and after treatment and determining the percentage of increase.

VARIOUS METHODS OF USING THE FORMALIN TREATMENT.

There are several simple methods of using the formalin treatment. Of these, sprinkling is one of the most convenient. The seed is



FIG. 7.—Simple apparatus for the formalin treatment, consisting of two half-barrel tubs, fitted with pine plugs and rope handles, and two sawhorses.

placed on a clean floor or canvas in a pile or layer several inches thick. It is then sprinkled with the formalin solution by means of an ordinary sprinkling can or spraying machine and is shoveled over and over until every kernel is thoroughly wet. The grain is then placed in a pile and covered with sacks, blankets, or a tarpaulin for two

hours or over night. It is then dried sufficiently to run through the drills, after which it may be sown.

This method is convenient and fairly effective for oats and barley, but should not be used for wheat when there are smut balls in the grain, as it does not provide for the removal of the smut balls and therefore is not thoroughly effective. Many simple and effective methods for immersing the seed in a formalin solution and for the removal of the smut balls are known, however, and are here described.

The first of these requires two tubs or half barrels with handles. A hole is bored at the bottom of each tub. This hole is fitted with a plug and covered with a wire screen on the inside of the tub so that

¹ One pint weighs approximately 1 pound.

grain can not pass through. One tub is set above the other, as shown in figure 7.

The upper tub is then filled two-thirds full with the formalin solution and the seed poured in. As the seed is poured in and stirred, smut balls, chaff, and light kernels rise to the surface and are skimmed off. When the skimming is completed the plug is removed, and the formalin solution is allowed to drain into the tub beneath. The grain is then removed and spread out to dry. The empty tub is placed on the ground, the other tub on the stand, and the process is continued, more of the solution being added when necessary.

A second method, shown in figure 8, requires a trough (*a*) and a tub (*b*), the trough having a hole in one end fitted with a plug (*c*). The end is divided off with a perforated tin plate (*d*) or wire screen, so as to permit rapid drainage, or the hole is covered with a wire screen so that grain can not pass through. The trough is filled two-thirds full with the formalin solution and the seed grain is poured

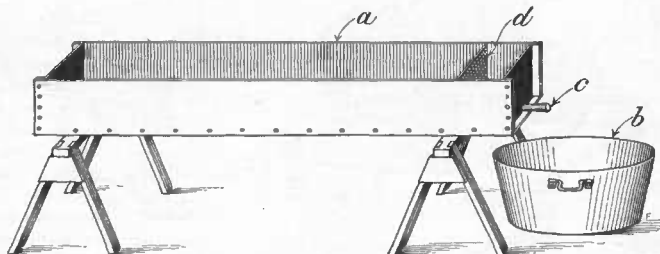


FIG. 8.—Simple apparatus for the formalin treatment, consisting of a trough, tub, and sawhorses: *a*, Trough; *b*, tub; *c*, pine plug; *d*, perforated tin plate.

into it. The smut balls, chaff, and light kernels rising to the surface as the seed is stirred are skimmed off. After a few minutes, or as soon as the skimming is completed, the formalin solution is drained off by removing the plug. The grain is shoveled out, the plug is replaced, the solution is poured back, with as much more added as is necessary, and then the process is repeated. This method is found convenient and two men can handle grain very rapidly in this way.

A third method is to use apparatus such as is shown in figure 9. Two tubs, a large one (*a*) and a smaller one (*b*), the latter made of substantial wire mesh or of iron or tin with perforated plate or wire bottom, are used and are so adjusted by means of handles (*e*), hinges (*d*), and block (*c*), that the wire tub can be easily raised and lowered inside of the larger tub. The tub (*a*) is two-thirds filled with the formalin solution, the other tub is set down in it, and the grain poured in and stirred. The smut balls, chaff, and light kernels

rise to the surface and are skimmed off. When this is done the tub (*b*) is raised by means of the handles, as shown in the illustration (fig. 9), the solution is allowed to drain off, and the grain is emptied on the floor to be shoveled away and dried.

These simple methods are recommended for use on the smaller farms, where there is little or no money for other than simple apparatus. On the larger farms it is both convenient and economical to use smut-cleaning machines, many types of which are on the market.

SMUT-CLEANING MACHINES.

Smut-cleaning machines are intended for use in wetting the grain thoroughly in a standard formalin solution. Two such machines, with a capacity of 25 to 50 bushels an hour, are shown in figures 10 and 11.

The seed is placed in the hopper and then passes into the formalin solution in the tank beneath.

As it sinks to the

FIG. 9.—Convenient apparatus for the formalin treatment, consisting of a strong wooden tub and a substantial wire-mesh tub. Tub *b* is adjusted by means of block *c*, hinges *d*, and handles *e*, so that it can be placed in and raised out of tub *a* with a minimum of labor.

bottom it is thoroughly wetted, while the smut balls, chaff, and light seed float on the surface and are removed by an automatic skimming device. The grain is raised out of the solution by the elevator, is drained as it passes up the incline, and is then dumped into sacks or other receptacles to be removed and dried. The seed has been not only thoroughly soaked in the formalin solution during the process, but the smut balls have been removed. This is one of the most important operations in treating wheat, because if left in the treated seed such smut balls easily break in handling in sacks and machinery, live smut spores again get on the seed, and the treatment is not successful.

Smut cleaners which treat the seed with the formalin solution and at the same time remove the smut balls are therefore strongly recommended for wheat and barley.¹

Oats are lighter than wheat or barley and tend to float on the surface during treatment. To overcome this the skimming device in some of the smut cleaners is arranged so it can be reversed and assist in immersing the seed.



FIG. 10.—One type of smut-cleaning machine for treating grain in a formalin solution. The automatic skimming device removes the smut balls which float on the surface of the liquid in the tank.

REASONS WHY SEED TREATMENTS ARE SOMETIMES INEFFECTIVE.

The copper-sulphate and formalin treatments have been known for many years and are very extensively used at present, particularly in the West. Usually they are successful, but occasionally they are not. There are several reasons for the failures. The formalin purchased at the local store may be too weak and the solution mixed according to directions is not then sufficiently strong to kill the smut. Moreover, if the solution is not made up in the right proportions it will either be ineffective, if too little formalin or copper sulphate and too much water are used, or if too much formalin or copper sulphate and too little water are used it will injure the seed. The mixtures must be substantially as recommended in this bulletin.

¹ Good smut-cleaning machines are on the market at prices ranging from \$25 to \$40. Local implement dealers should be consulted about them.

One thing, moreover, which contributes more than anything else to the supposed inefficiency of seed treatments is that the smut balls are left in the seed. The seed is usually dipped while in sacks or the solution is sprinkled on the seed while in piles. Although this is fairly satisfactory for oats and for barley, neither method gives a chance to remove the smut balls from the wheat.

Water as a rule can not soak into unbroken smut balls, and therefore the smut spores contained in them remain uninjured by the solution. When the smut balls afterwards break in handling in sacks and machinery these spores get on the seed and infect it, causing smut in the succeeding crop. It is absolutely necessary to remove these smut balls in order to assure a clean crop.

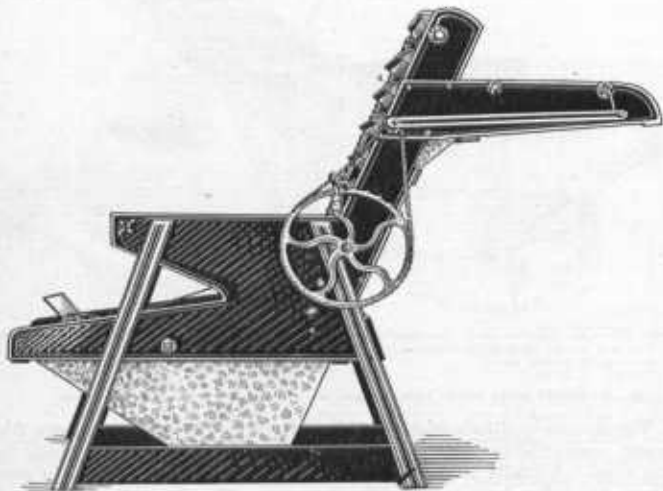


FIG. 11.—A second type of smut-cleaning machine for treating grain in a formalin solution. This machine also is fitted with an automatic skimming device for removing smut balls.

Again, seed after being carefully treated is placed in sacks, bins, or machines which have contained smutted grain and have not been disinfected. The smut spores left in these implements and bins get on the treated seed and infect it. This is particularly true in regions where smut is very abundant, as there practically every sack, bin, or implement in which smutted grain has been handled contains innumerable smut spores. Contamination of grain a second time by such means, however, can be prevented by disinfecting all sacks by soaking

them in a formalin solution of the same strength as that used for treating the seed and all bins and machinery by washing all parts which will come in contact with the grain with a solution two or three times as strong as that used for treating the grain. When such precautions are taken there is usually very slight cause for complaint that treatments are not effective.

In parts of the semiarid grain-producing areas and in the Palouse country of the Northwest, however, the smut balls often break while the grain is standing in the field and large quantities of spores are thus liberated, while other innumerable thousands are set free in the air when harvesting is done with the combined harvester and thrasher. These are distributed by the wind, and when they fall in large quantities on ground where winter wheat will be sown, some spores may come in contact with the planted grain and cause considerable infection. This is often very noticeable when winter wheat is sown where a thrashing outfit has thrashed smutted wheat. Smut is then often found more abundantly in a small area around this place than on any other part of the field. At times this smutted area has been observed to be fan shaped, extending in that direction from the machine toward which the wind was blowing when the thrashing was done. Great quantities of spores liberated during thrashing fall on these areas, and when wheat is sown some of it comes in contact with the spores and infection takes place.

That the smut spores may live from one year to another on or in the soil in considerable numbers is undoubtedly true, but to what extent has not yet been fully demonstrated. In spring-grain areas most of the smut spores falling on the ground in the autumn undoubtedly germinate and die before the grain is sown. Some, however, which have remained frozen during the winter may germinate sufficiently late in the spring to infect a small percentage of the succeeding crop. This has been proved to be the case in Minnesota by recent experiments of the Office of Grain Investigations in cooperation with the Minnesota Agricultural Experiment Station. A quantity of smut spores was scattered on a small plat and raked into the soil in the fall. Clean seed planted on this land in the spring produced a crop which contained a few smutted plants, while seed from the same bulk planted on an adjacent plat on which smut spores had not been scattered produced a clean crop. The percentage of smut which is caused in this way, however, is apparently very small, and if every-one treated with care all the seed sown there probably would be very little cause for complaint that the smut spores live from one year to another in the soil.

INCREASE IN PRODUCTION RESULTING FROM PROPER TREATMENT OF THE SEED.

When the treatment has been properly performed, treated seed with few or no exceptions gives better yields than untreated seed, primarily because there will be no smutted plants to take the place

of sound plants. Thus, if untreated seed produces a crop of 20 bushels of wheat to the acre when 10 per cent of the heads are smutted, the same seed if treated would produce a crop at least 10 per cent larger, or 22 bushels per acre. On 100 acres this would mean an increase of 200 bushels. It has been found by actual experience, however, that the increase in production of treated over untreated seed is not only as much but more than it would be if all smutted heads were replaced by sound heads. This undoubtedly results not only because many plants from untreated seed which do not produce smutted heads may be more or less stunted by smut, but also because the spores of other diseases which might infect the young plants, but which generally are regarded as more or less unimportant, are also destroyed, thus allowing the grain to get a healthy and vigorous start. Seed treatments, therefore, can not be too strongly urged, not only to increase the profit of the individual farmer but to increase the production of the country as a whole.

TREATMENT FOR THE LOOSE SMUTS OF WHEAT AND BARLEY.

The treatments for the loose smuts of wheat and barley are different from those described for the stinking smut of wheat, covered smut of barley, and the smut of oats. This is because the loose smuts infect the embryo, or germ, of the seed and are not carried from crop to crop by spores clinging to the outside of the seed. Disinfecting the surface of the kernels only, as is done for the other smuts, is therefore useless, as it is necessary to destroy a tiny smut plant which is lodged in the germ itself. Although this seems difficult, it can be done without injury to germination by using the so-called modified hot-water treatment of the seed.¹ This consists of soaking the seed in cold water and then treating it in hot water. The smut plant, being weaker than the embryo of the seed, is killed and the seed is not injured. It has been found by experiment that this treatment will prevent not only the loose smuts but also the other smuts of wheat and barley. However, to be effective and at the same time not to injure the seed, this treatment must be applied with care.

METHOD OF USING THE MODIFIED HOT-WATER TREATMENT.

The seed is soaked in cold water in tubs, barrels, or vats for four or five hours. The soaking must not exceed six hours or be less than four hours. It is then removed, immediately drained, and treated in hot water. Barley is treated for 13 minutes at 126° F. and wheat for 10 minutes at 129° F. The apparatus necessary is the same as that

¹The modified hot-water treatment was first devised and used for loose smut of barley by Jensen in Denmark in 1887-1889. (See Journal of the Royal Agricultural Society of England, ser. 2, vol. 24, pt. 2, 1888, and *Le Charbon des Cereales*, Copenhagen, 1889.) Kellerman and Swingle, on the strength of Jensen's work in 1889, recommended this treatment for loose smut of barley in this country. Swingle in 1894 first recommended the treatment for loose smut of wheat. It has been tried by many investigators in this country and abroad and was thoroughly tested, improved, and recommended by Freeman and Johnson in 1909. (See Bulletin 152, Bureau of Plant Industry, U. S. Dept. of Agriculture.)

described for the ordinary hot-water treatment on pages 16 to 18, and the method of treatment is the same. The temperature of the water in barrel No. 1, in which the grain is dipped for a moment before being placed in the regular treatment, should be 120° F. The temperature of that in barrel No. 2 must be more carefully controlled than in the ordinary hot-water treatment, however, as seed which has been soaked five hours is more easily injured than unsoaked seed. If the temperature should rise to 127° F. when treating barley, the time of treatment must be reduced to ten minutes, and to five minutes should the temperature rise to 129° F.; otherwise the seed will be injured. Water heated above 129° F. must not be used. If the temperature falls below 126° F., the period of treatment must be increased in proportion or the smut will not be killed. A temperature lower than 124° F. will not be effective. In a similar manner in treating wheat, if the temperature should rise above or fall below 129° F. the time of treatment must be diminished or increased accordingly. Temperatures above 131° F. must not be allowed, as they will injure the seed. Temperatures below 124° F. will not kill the smut.

In any hot-water treatment care must be taken that all the seed becomes equally heated, but this is particularly true of the modified hot-water treatment. This can be accomplished only by treating comparatively small quantities of seed at one time. The basket which is being dipped should never be more than half full of seed and should be moved up and down so that the water may flow freely through it and every kernel become equally heated.

By reason of the care necessary in performing this treatment, its use at present is recommended principally in connection with a seed plat on which the grain to be used for seed the following year is grown. Such a seed plat is described in Bulletin 152 of the Bureau of Plant Industry, and the following paragraph is copied from it:

THE SEED PLAT AND ITS USE.

A good, clean, well-cultivated piece of land should be selected and set aside for the raising of seed for the succeeding year. For this plat seed should first be carefully cleaned and selected by the best fanning and sifting processes. This seed should then be treated as directed above. The plat ought to be large enough to provide at least twice as much grain as will be necessary for farm seed the following year, in order to allow for loss in cleaning and selecting. This seed plat must not be placed next to fields of smutted crops of the same cereals. The plat ought also to be located so that the prevailing winds at flowering time will not carry spores to the seed plat from a neighboring field of the same grain. The isolation of this plat from smutted crops of the same cereal is absolutely necessary, not only from crops on the owner's farm but from neighboring farms as well. A strip of wood, a cornfield, a large meadow, or a barley or oat field intervening between the wheat seed plat and fields of smutted wheat will be useful, and similarly a field of corn, oats, or wheat or a large meadow or strip of wood between the barley-seed plat and the smutted

field will be a valuable protection. This point can not be too strongly emphasized and the cooperation of neighbors may be necessary to carry it into effect.¹

The seed plat should be maintained from year to year, at least as long as any smut is present on the farm. The seed-plat system for the raising of an extra good quality of grain for seed can not be too highly recommended. In connection with such a system the modified raising of an extra good quality of grain for seed can not be too strongly urged on seed growers and farmers who want to grow the cleanest seed and the largest grain crops possible.

PREVENTION OF THE SMUT OF CORN.

As already mentioned, the smut of corn is not caused by sowing smutty seed. Seed treatments for disinfecting purposes, therefore, are entirely useless. It is possible, perhaps, to reduce the quantity of this smut by going through the fields when it first begins to appear and cutting out and burning all smut masses wherever found. To be at all effective, however, this should be done before the smut boils begin to turn black and break open, because as soon as this happens an enormous number of spores escape into the air and are widely distributed. This method of combating the smut takes much labor, and whether such work gives sufficient returns to be highly recommended has not yet been demonstrated.

Where much smut from the preceding crop has been brought into the barnyard in fodder and such fodder has been fed to cattle many live smut spores are to be found in the manure. These not only live over winter on the old stalks and in manure but also may go through the alimentary canal of animals without being injured. In fact, smut will produce its second crop of spores in the manure pile in great abundance. Manure known to be infected, therefore, should be well composted before it is used on land where corn is to be grown.

Some varieties of corn undoubtedly are more resistant to smut than others, but there are so many other factors, such as vigor, yielding power, etc., which enter into the selection of a variety of corn for a certain locality that little or no attention has as yet been paid to this phase of the problem.

ERADICATION OF SMUTS BY ORGANIZED EFFORT.

The methods for the prevention of the smuts of wheat, oats, and barley which have been discussed and recommended in this bulletin can be applied by individual farmers from year to year and smuts in their crops prevented, but the effectiveness of these methods can be greatly increased and clean crops can best be obtained if whole communities systematically undertake smut eradication. That it is possible to do this, particularly with the stinking smut of wheat, the smut of oats, and the covered smut of barley, can not be doubted if the progressive and influential farmers in a grain-raising community

¹Freeman, E. M., and Johnson, E. C. The Loose Smuts of Barley and Wheat. Bulletin 152, Bureau of Plant Industry, U. S. Dept. of Agriculture, p. 39.

will organize with this object in view. Such an organization could have for its general purpose the production of better grains and for its particular object the eradication of smuts. As soon as the organization is formed and the necessary capital raised among the members, smut-cleaning machines and drying apparatus which could be used first at one farm and then at another should be secured, or a central treating plant should be established where the farmers could take their seed to be treated at the actual cost of labor and running expenses. These treating plants need not be expensive and could be established independently or in connection with farmers' elevators, cooperative creameries, or other cooperative institutions. In Denmark, for instance, a number of treating plants in connection with creameries are already in operation. These have been erected at a cost of \$100 to \$200 each, and the farmers may have their grain treated with the modified hot-water treatment, the most expensive of all treatments from the standpoint of labor, at a cost of less than 3 cents a bushel.¹

With the efficient treatment of seed in this manner clean crops would soon result. In order that they may remain free of smut, machines employed only in thrashing clean crops should be used, as machinery which has thrashed smutted crops, unless it can be thoroughly cleaned and disinfected by some method not yet fully demonstrated, contains and distributes spores of stinking smut of wheat, smut of oats, and covered smut of barley from one farm to another. If other farmers in a community were also compelled by popular opinion or State law to disinfect their seed and use smut-free thrashing outfits, smuts would soon be eradicated from such districts and treatments, except of such seed as might be shipped in from other localities, would be unnecessary for long periods.

Another method which would accomplish the same purpose, perhaps more easily than the first, would be for similar organizations of farmers to ascertain from the State experiment stations, the United States Department of Agriculture, or by actual experimental tests the varieties of wheat, oats, or barley best suited to their localities and to make a specialty of seed production. By treating the seed for a few years, using cooperatively owned thrashing machines, and by disinfecting all sacks, bins, and machinery, as previously described in this paper, seed absolutely free of smut would soon result. Provided these farmers would not demand an excessive price for their grain, other farmers in the vicinity would soon wish to secure seed from them and after using such seed for a few years smut would disappear from the community. Treatments would soon be unnecessary except for grain shipped in from other localities. Communities of this kind would soon gain reputations as centers for the production of clean seed and the farmers would profit not only by the

¹ Afværvampning af saarsæd paa Mejerierne. Landmansblade, vol. 42, no. 14, 1909, pp. 181-186, and *ibid.* no. 15, pp. 193-195.

elimination of the necessity for seed treatment and the increased production due to absence of smut, but also would be able to command a premium on grain which had a reputation for being of high-yielding quality and free from smut.

The beneficial results of community and cooperative effort both in production and in marketing, as evidenced by the numerous successful cooperative creameries, farmers' elevators, truck and fruit growers' associations, and other organizations, have been marked within the last few years, and there is no doubt that by similar organized effort smut eradication, resulting in greatly increased grain production, can also be successfully undertaken.

SUMMARY.

Methods for preventing the more important grain smuts have been known and used in this country since about 1890. Losses from smuts, however, are still surprisingly large, and in 1911, exclusive of the losses from smut in corn, were conservatively estimated at \$35,981,982 for the United States. Lack of information, time, and money, the incorrect use of preventive methods, and the lack of community effort are largely responsible for these losses.

The stinking smut of wheat is distinguished by light-weight heads, dark swollen kernels, spreading of the chaff, and fetid odor.

The loose smut of wheat is distinguished by the dark sooty masses which appear at heading time and are soon blown away, leaving a bare stalk.

The covered smut of barley is most noticeable a little before the grain is mature. The kernels in smutted heads are composed of greenish black masses of smut, which as a rule are not blown away.

The loose smut of barley, like the loose smut of wheat, is most conspicuous at heading time, when dark, sooty masses appear, which soon are blown away, leaving the stalks bare.

The smut of oats is most noticeable a little before the grain is ripe. The kernels are replaced by dark masses of smut dust, which sometimes are covered by the chaff and sometimes are left fully exposed.

The smut of corn occurs on any part of the corn plant and forms large, dark smut boils, or smut masses.

The smuts are plants which live in the tissues of other plants, such as grains and grasses, and produce dark, sooty masses of smut.

There are many kinds of smut which are entirely distinct, although they resemble each other.

The smutted kernels in stinking smut of wheat are composed of thousands of smut spores which are mature when the grain is ripe and are distributed in thrashing and handling the grain. When smutted seed is sown and germinates, the smut spores also germinate, and smut plants are started which infect the wheat plants and develop smut masses at maturity.

The life habits of covered smut of barley and smut of oats are similar to those of stinking smut of wheat.

The loose smuts of wheat and barley mature and distribute their spores at the flowering time of the grain. These spores fall in the open flower, infect the developing kernel, and form a tiny smut plant inside the seed. When this seed is planted a smutted plant is again produced.

The smut masses in corn contain hundreds of thousands of spores, which may remain on old cornstalks, on the ground, or in manure and germinate in the spring, forming numerous other tiny spores. These are distributed by the wind, and when they fall on young parts of the corn plant infection takes place and new smut masses are produced.

The smuts naturally fall into three groups. To the first belong stinking smut of wheat, covered smut of barley, and smut of oats, whose spores are mature when the grain is ripe and lodge on the outside of the seed; to the second, the loose smuts of wheat and barley, whose spores are mature when the grain is in bloom and are distributed by the wind, infecting the flower and forming a tiny smut plant inside of the seed; to the third belongs the smut of corn, the spores of which generally mature before the corn is ripe and live from season to season on the ground, on old cornstalks, and in manure.

Clean seed is of prime importance in order to grow smut-free wheat, oats, and barley. For the first group of smuts mentioned in the preceding paragraph, this can best be secured by proper disinfection of the seed; for the second group, the use of clean seed from a seed plat sown with disinfected seed is the best remedy; while for the third, clean seed will not insure a smut-free crop and seed treatments are useless.

Stinking smut of wheat, smut of oats, and covered smut of barley may be prevented by treating the seed in some liquid which will kill the smut spores but will not injure the seed. Hot water, sar solution, copper-sulphate, and formalin solutions have been used for this purpose. Hot water and the formalin solution are recommended.

The hot-water treatment for stinking smut of wheat and smut of oats consists in soaking the seed in water at a temperature of 132° to 133° F. for 10 to 15 minutes. It may be applied in different ways. The seed should always be tested for germination before sowing.

The hot-water treatment for covered smut of barley is performed like that for stinking smut of wheat, but at a temperature of 126° to 129° F.

The sar treatment consists in soaking the seed in a mixture of flowers of sulphur, powdered rosin, caustic soda, and water, and is effective in preventing stinking smut of wheat, smut of oats, and covered smut of barley.

The copper-sulphate treatment consists in dipping the seed in a solution of copper sulphate in water. It has been used for stinking

smut of wheat, but it injures the seed to some extent and should not be used for the smuts of oats and barley.

The formalin treatment, which consists of sprinkling or soaking the seed in a solution of formaldehyde in water, is a very desirable treatment for stinking smut of wheat, smut of oats, and covered smut of barley and is strongly recommended as a preventive.

There are various methods for using the formalin treatment. Of these, sprinkling the seed with the solution is a convenient and fairly effective method for oats and barley but should not be used for wheat. For wheat, immersion of the seed in the liquid and the removal of the smut balls is most effective. On small farms, simple but effective apparatus for immersing seed in the formalin solution can be devised and used, while on larger farms smut-cleaning machines are recommended. All methods of treatment of wheat seed should provide for the removal of the smut balls from the seed.

Seed treatments are sometimes ineffective for various reasons: The treating solutions may not be of the required strength, the treatments are carelessly or incorrectly performed, and the smut balls are left in the seed, or the seed after treatment is placed in sacks, bins, or machines which contain live smut spores.

In parts of the dry-land areas it is probable that spores blown from smutted fields to fallowed land which is sown to winter wheat may cause considerable infection. In spring-wheat areas probably a very small percentage of infection occasionally occurs from spores which have wintered on or in the soil.

Properly treated seed gives better yields than untreated seed because sound plants take the place of smutted plants and the spores of other diseases which might infect the young plants to some extent are also destroyed.

The loose smuts of wheat and barley can not be prevented by disinfecting the surface of the seed. The modified hot-water treatment, which consists of soaking the seed in cold water and then treating it in hot water, when correctly applied will kill the smut plant, which is weaker than the embryo, but will not injure the seed. This treatment is recommended principally in connection with the seed-plat system.

Smut in corn can not be prevented by treatment of the seed, but its quantity can probably be reduced by cutting out and burning the smut boils when they first appear. Manure from barnyards where smutted corn fodder or corn has been used should be composted before it is placed on corn land.

The effectiveness of preventive methods for smuts can be greatly increased and smut eradication best accomplished if whole communities, by organized effort, will employ the best-known methods to eliminate smuts. After a few years smuts of small grains would disappear from such communities and grain production would be greatly increased.